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Updated reference point estimates for northern Gulf of St. Lawrence (3Pn4RS) cod (*Gadus morhua*) based on revised beginning of year weights at age

Mise à jour des points de référence estimés pour la morue (*Gadus morhua*) du nord du golfe du Saint-Laurent (3Pn4RS) basée sur les poids à l'âge en début d'année

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ABSTRACT

Reference points for northern Gulf of St Lawrence (nGSL) cod were updated from the estimates presented at the 2009 cod zonal assessment process held in St. John's (Duplisea and Fréchet 2009) owing to recent changes to the weight at age vector used for the calculation of spawning stock biomass (SSB). The new weight at age vector are based mostly on surveys corrected to January of each year rather than the weight age vector from the commercial fishery. The result of this change is that weight at age used for SSB calculation has decreased in all age classes though this does not affect abundance at age. Consequently, the previous estimate for the limit reference point declined from 140,000 t to 116,000 t and the upper stock reference point based on the recruitment plateau decreased from 200,000 t to 180,000 t. It is emphasised that changes to reference points here are mostly due to rescaling SSB and though it may change the perception of stock size, the actual abundance of fish in the water did not change in the VPA. Because the commercial weight at age vector is still used for TAC calculation and risk analysis, these are unaffected by the change in weight at age vector for SSB calculation.

RÉSUMÉ

Les points de référence pour la morue du nord du golfe du Saint-Laurent (nGSL) furent mis à jour à partir des estimés présentés lors de la revue zonale tenue en 2009 à St. Johns (Duplisea et Fréchet 2009) en raison des récents changements apportés au poids à l'âge utilisé pour le calcul de la biomasse du stock reproducteur (BSR). Les nouveaux poids à l'âge sont basés principalement sur les données des relevés, ramenées en janvier de chaque année plutôt que sur les poids à l'âge de la pêche commerciale. Comme résultat, le poids à l'âge utilisé pour le calcul de la BSR a diminué pour toutes les classes d'âge bien que cela n'affecte pas l'abondance à l'âge. Par conséquent, l'estimation précédente du point de référence limite a diminué de 140 000 t à 116 000 t et le niveau de référence supérieure basé sur le plateau de recrutement a diminué de 200 000 t à 180 000 t. Ces changements apportés aux points de référence sont principalement dus à un rééchelonnement de la BSR et bien qu'elle puisse modifier la perception que l'on a de la taille du stock, l'abondance actuelle de poisson dans l'eau n'a pas changé dans l'ASP. Parce que le poids à l'âge provenant de la pêche commerciale est encore utilisé pour le calcul du TAC et l'analyse de risque, ceux-ci ne sont pas affectés par le changement du poids à l'âge dans le calcul de la BSR.

INTRODUCTION

In May 2010 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) declared that the Laurentian North population of cod (which includes Northern Gulf of Saint Lawrence (3Pn4RS) and southern Newfoundland (3P) cod) as an endangered population. DFO as the government authority delegated management duties for this stock by the people of Canada as owners of stock must consider the recommendation of COSEWIC and balance the social, economic implications for Canadians and biological implications for the stock and ecosystem for listing the stock under the Species At Risk Act (SARA). A listing of endangered under SARA obliges DFO to develop a recovery plan for the stock commonly termed a recovery potential assessment. Clearly assessing recovery requires that a fully developed precautionary approach is in place for the stock including scientifically sound definitions of recovery.

The present work is an update of reference points estimated for northern Gulf of St Lawrence (nGSL) cod in 2009 taking into account a new weight at age vector for fish in the sea which affects the perception of stock size when cast in spawning stock biomass (SSB) terms. The previous weight at age was from the commercial fishery conducted primarily in the summer and fall. The newly accepted weight at age is from surveys conducted either in January or in the summer and then corrected to January weights.

The 2009 research document (Duplisea & Fréchet 2009) detailed the methodology for reference point estimation and included code in R for their calculation. Here we provide merely an update on the reference points with the new data and a brief description.

METHODS

DATA

The data used here are from accepted ADAPT (Cohort reconstruction method - (Gavaris 1988) model run for nGSL cod from 2010 cod evaluation (DFO 2010). All the methods proposed here use spawning stock biomass (SSB) and recruitment at age 3 (R) series generated from ADAPT or in the case of the Bloss reference point (see below) only the SSB series (Annex 1).

The weight-at-age vector for SSB calculation was modified in 2010 to reflect beginning of weight back calculated from trawl surveys rather than mid year weights from commercial fisheries. The new weights at age for the beginning of year were taken from the RV survey vessel *Gadus Atlantica*, no transformations were needed as the survey was conducted in January. The 1974 to 1978 period was set at the average observations for the vessel during the 1979 to 1981 period. No survey was conducted in 1982 so the 1983 to 1985 period values were used. The actual values observed for the 1983 to 1994 period were used. From 1995 to 2009, the observed August DFO survey values were used and corrected back to January by the Rivard method (http://nft.nefsc.noaa.gov/Rivard.html#Version). The 2010 values are the average of the 2007 to 2009 period.

The SSB in 2010 using commercial weights at age would be 27,754 t and using the new beginning of year weights at age would be 16,291 t. As was noted earlier, the total population estimates are unchanged.

LIMIT REFERENCE POINTS

Here we estimated limit reference points by eight different methods (Table 1). These are roughly broken into three groups: "parametric" meaning that they are derived from fitting a parametric stock-recruit curve, "non-parametric" meaning that they are derived from non-parametric fitting methods, "empirical" meaning that they are based purely on some characteristic of the time series trend, e.g. lowest point. Furthermore, within the non-parametric group, two new reference points were estimated based on the fitting of the non-parametric smoother curve fit to the stock-recruit data: Binfl and P0.1. A detailed description of these reference points as well as methods and code for estimating them can be found in the original document (Duplisea & Fréchet 2009).

Table 1: a summary of reference points calculated here for 3Pn4RS cod. Binfl and P0.1 are new point introduced here and are discussed later in the document

NAME	DESCRIPTION	GROUP	POINT	EVALUATION	KEY REFERENCES
BH50	Beverton-Holt curve SSB @ 50% maximum recruitment	parametric	Blim	peer reviewed	(Myers *et al.* 1994)
HS50	Hockey stick curve SSB @ 50% maximum recruitment	parametric	Blim	peer reviewed	(Barrowman and Myers 2000); (O'Brien *et al.* 2003)
RK50	Ricker curve SSB @ 50% maximum recruitment	parametric	Blim	peer reviewed	(Myers *et al.* 1994)
NP50	Non-parameteric curve SSB @ 50% maximum recruitment	non-parametric	Blim	peer reviewed	(DFO 2004)
Binfl	Point of maximum change in R with a 1000 t change in SSB from smoother (NP50) curve	non-parametric	Potentially both Blim, Busr	not peer reviewed	
P0.1	SSB at 10% of cumulative smoother (NP50) recruitment predictions	non-parametric	Blim	not peer reviewed	
Sereb	Serebryakov 90% recruitment with 90% survival	non-parametric	Blim	peer reviewed	(Serebryakov 1991);(Myers *et al.* 1994); (DFO 2004)
Bloss	Lowest SSB from which there has been a recovery or 20% maximum SSB	empirical	Blim	peer reviewed	(ICES 2007)

UPPER STOCK REFERENCE POINT

In the Fisheries and Oceans policy, the upper stock reference point (USR) should be determined by industry and management aided by science. Accordingly, we, as DFO scientists, suggest a method for estimating an USR for nGSL cod based on biological criteria.

A USR was estimated here as the lowest SSB where further increases in SSB did not produce markedly improved recruitment. Thus the USR estimated in this way embodies concepts of density dependent suppression of population production and has some similarities to the biomass at maximum sustainable yield (B_{MSY}).

RESULTS AND DISCUSSION

LIMIT REFERENCE POINT ESTIMATES AND RECOMMENDATION

Eight different limit reference points are shown here most of which are based on stock-recruit concepts (Figure 1).

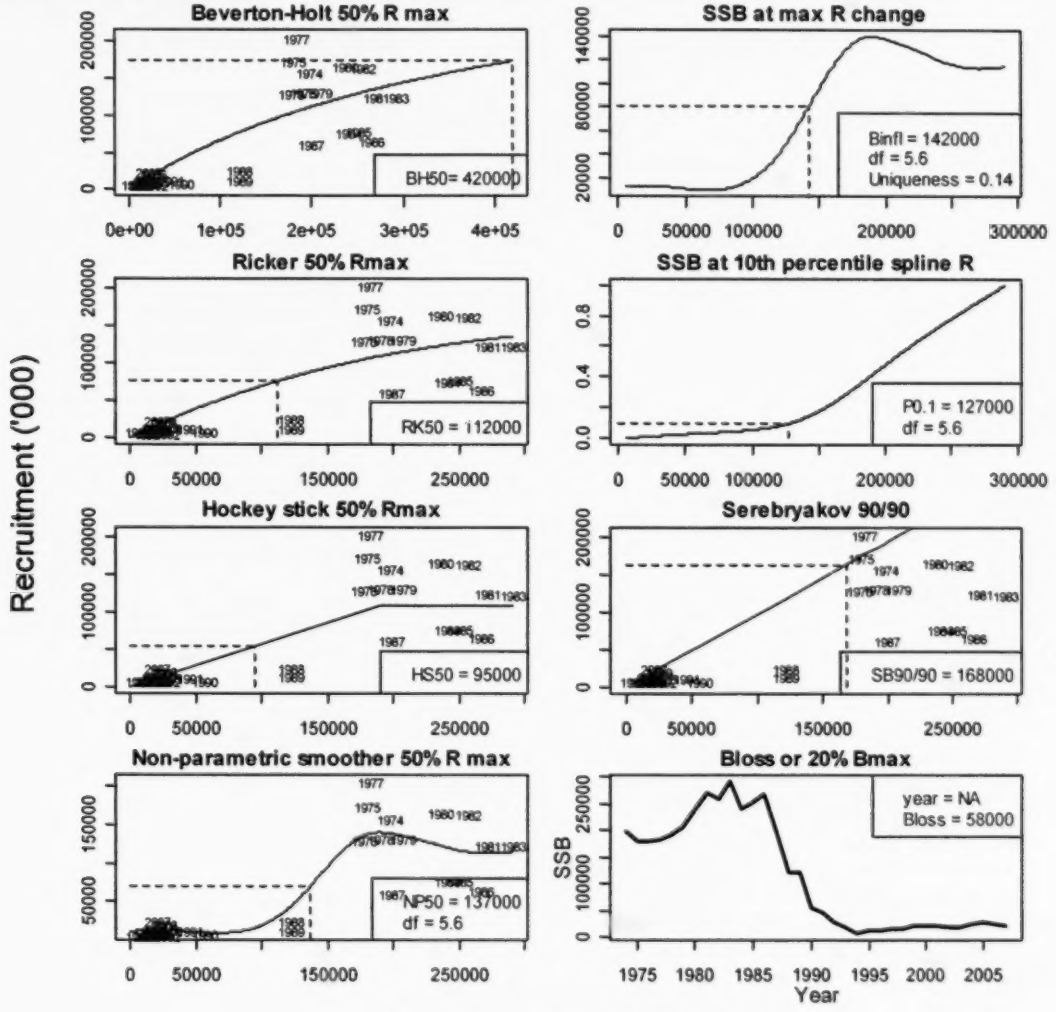

Figure 1: Limit reference point estimates for 3Pn4RS cod based on numbers at age from the 2010 peer reviewed assessment and beginning of year survey weight at age for biomass calculation.

<u>Credibility of different reference points for 3Pn4RS cod in 2010</u>

Our evaluation of reference point methods did not change from the previous evaluation (Duplisea & Fréchet 2009) where the Hockey-Stick and Non-parametric smoother SSB at 50% of maximum R were considered credible estimates while other methods were rejected (Table 2).

Each new fitting of reference points must be critically evaluated even when methods and points have previously been accepted. The reason for this is that most of these points depend on assessment model fitting and with the addition of new data, model fits can change and not always in terms of statistical improvement. For example it is becoming evident that when there is error in stock size estimates resulting from increased measurement error or increased variance in stock size, many stock-recruit based methods will underestimate the true limit reference point values (Cadigan 2009). For this reason, it would be wise to consider limit reference point estimates as liberal for stock which have explored a large part of the R-SSB space. New data could reveal characteristics of stock productivity never before observed and this could increase the uncertainty associated with model fits. Likewise, any change in productivity regime could invalidate reference points. For example, if mean productivity for the period represented by the current estimates was relatively low, then an increased productivity situation would make the points more conservative and vice versa for a decrease in productivity. For these reasons, it is wise to regularly (but not too frequently) undertake a revaluation of the reference point framework.

Given our credibility analysis of the reference points applied to 3Pn4RS cod, we consider two reference point estimates as credible values for Blim: HS50 and NP50. The non-parametric curve has a significantly better fit than the hockey stick but at the price of using more degrees of freedom. The non-parametric curve also joins the two clouds of SR points characteristic of this stock in a depensation like manner. If it were accepted that this stock displays depensation then a proper depensation like parametric curve should be fitted (e.g. Myers et al. 1995) though this would be an important assumption with serious implications for stock management. Given that both the hockey stick and non-paramtric fits have strengths and weaknesses yet both are credible, our choice for the limit reference point has been to average the two estimates. For the most recent accepted ADAPT run with the new weight at age these estimates were 95,000 t and 137,000, respectively. Thus a biomass limit reference point of 116,000 t SSB was calculated as a mean from the two estimates.

We note, once again (DFO 2003, Duplisea & Fréchet 2009), that in the interval 100,000 – 200,000 t SSB there are few observations. We therefore consider it to be speculative to suggest such a precise estimate for the reference point. Given that current fisheries are estimated to be removing biomass of the stock at the equivalent of about its surplus production, it seem unlikely that the stock will grow to an SSB in this range for many years without a significant change in the management priorities for the stock. We are therefore unlikely to know more about the characteristics of the stock productivity in this relatively unexplored SSB range for a long time and a more accurate estimate of Blim will probably not be forthcoming.

Table 2: Limit reference point estimates for 3Pn4RS cod based on numbers at age from the 2010 peer reviewed assessment and beginning of year survey weight at age for biomass calculation. Credibility of the points is assessed and main reason for that assessment described

Name	LRP estimate	credible	Reason
BH50	420,000	No	Model not significant, LRP extrapolated
HS50	95,000	Yes	Simple assumptions
RK50	112,000	No	Model not significant
NP50	137,000	Yes	No parametric assumptions
Binfl	142,000	No	Not peer-reviewed, not consistent with serious harm
P0.1	127,000	No	Not peer-reviewed
Sereb	168,000	No	Pathological behaviour
Bloss	NA	NA	Does not exist for this stock

UPPER STOCK REFERENCE POINT ESTIMATE

The upper stock reference point for 3Pn4RS cod was 180,000 t. This was based on the dividing the two clouds of stock-recruitment data points for this stock (higher cloud: 1974-1987, lower cloud:1988-2010) (Figure 2). The exact value for the point was taken as the mean SSB for the years 1975, 1976 and 1977.

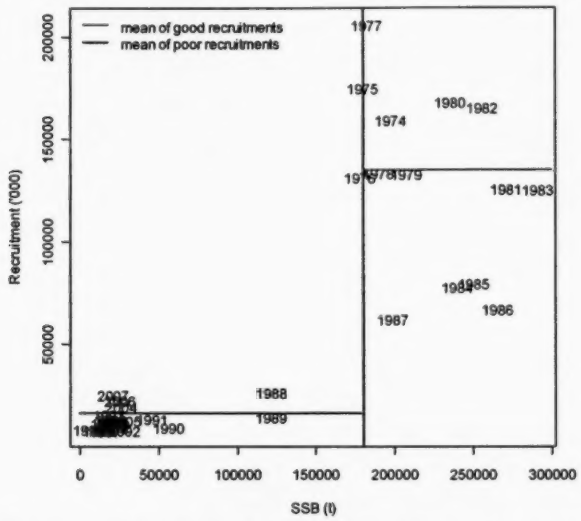

Figure 2: Upper stock reference point estimate for 3Pn4RS cod based on numbers at age from the 2010 peer reviewed assessment and beginning of year survey weight at age for biomass calculation. The point is defined as the lowest biomass giving "good" recruitment.

Other methods could be used to estimate the upper stock reference point but there is unlikely to be a method which can be so easily explained and defended as logical. The parallels of this method with Bmsy adds credibility to the method. Given that 3Pn4RS cod stock-recruit scatter shows two distinct clouds, this method is well justified, unambiguously estimated and it does not suffer from problems of interpolating between what some might consider two distinct productivity regimes.

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ANNEX 1: STOCK-RECRUITMENT DATA

The stock-recruit data set from the 2010 ADAPT run (DFO 2010) are presented here lagged by three years to account for recruitment (thousands) at age 3 (thus the year represents the year of birth for the recruits and the SSB (t) that produced that year-class). The SSB has been updated to reflect weight at age at the beginning of the year from surveys.

year	R ('000)	SSB (t)
1971	106293	NA
1972	136678	NA
1973	116014	NA
1974	159677	197850
1975	175084	180104
1976	131753	178109
1977	205992	182460
1978	133570	190156
1979	133314	207543
1980	168063	235882
1981	126169	271086
1982	165603	256478
1983	125679	291145
1984	78224	240296
1985	79796	250713
1986	67302	265940
1987	62698	198773
1988	27172	121342
1989	14810	121325
1990	9890	56422
1991	14044	45857
1992	8578	28601
1993	16192	18097
1994	8979	5336
1995	8434	11849
1996	8293	13567
1997	8189	16026
1998	12104	16773
1999	11369	21627
2000	9682	20497
2001	12301	20584
2002	13840	19595
2003	13560	19743
2004	20143	25893
2005	13265	29048
2006	23210	25537
2007	25776	20956
2008	NA	16472
2009	NA	17008
2010	NA	16291